Volume 10
Number 125 *The biology of the four-lined borer Luperina Stipata (Morr.)*
Article 1

May 1930

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May, 1930 Research Bulletin No. 125

The Biology of the Four-Lined Borer *Luperina Stipata* (Morr.)

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IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

ENTOMOLOGY SECTION

AMES, IOWA

CONTENTS

SUMMARY

1. The four-lined borer, *Luperina stipata* (Morr.), is a native insect, normally feeding upon slough grass, but occasionally causing considerable "dead heart" damage to corn.

2. There is but one generation each year. The overwintering eggs hatch during late April or early May, and after a growing period of from 10 to 14 weeks the larvae pupate. The moths emerge during the fore part of August and deposit eggs for the next year's brood.

3. Quality of food and temperature materially affected the length of larval life of laboratory specimens. Apparently quality of food (succulent versus woody) determined the amount of growth (as measured by the increase in width of successive head capsules) that occurred during a stadium and the number of molts required to complete development. On the other hand temperature determined the rate of development (as measured by the duration of the individual stadia).

4. Natural enemies play an important part in holding this insect in check. The 21 species of parasites and predators are represented by: two Diptera, seven Hymenoptera, four Coleoptera, three Hemiptera, two mammals and three diseases.

5. Borers collected from *Spartina* were parasitized, but those taken from corn were free from parasites.

6. Elimination of slough grass from fence rows and burning the heavily infested grasslands between Nov. 1 and April 1 are recommended as means of control.

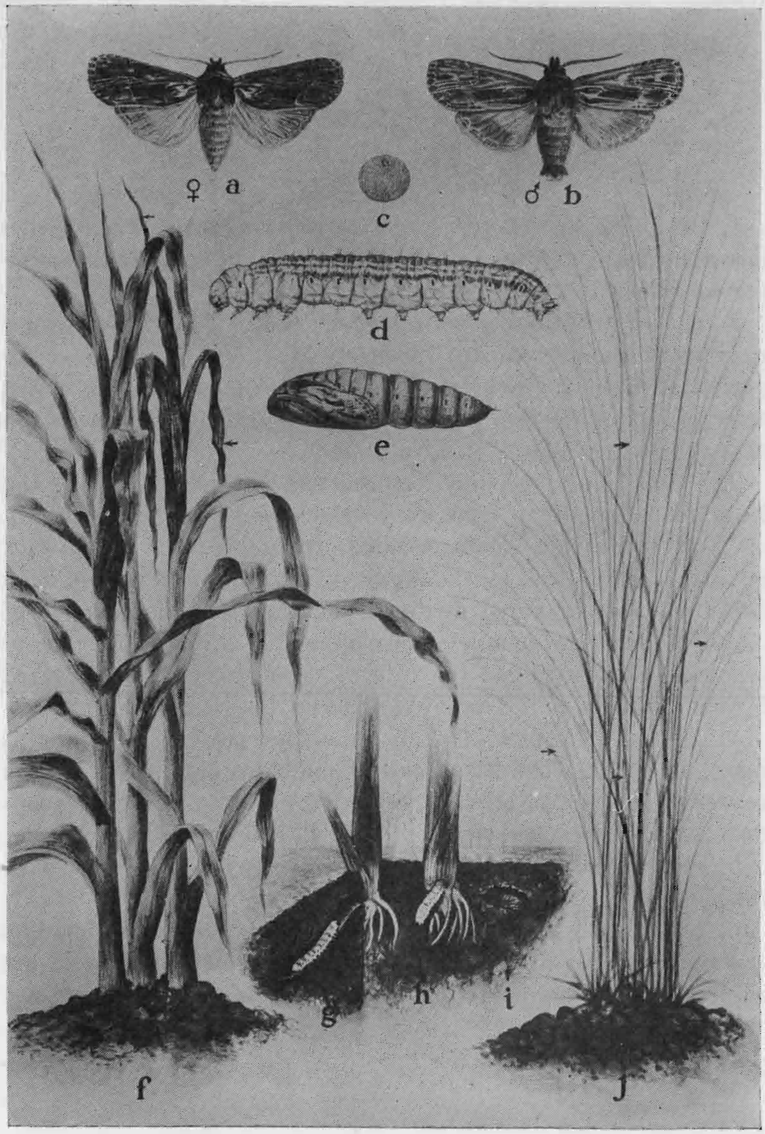

Fig. 1. a. Adult female; b. Adult male; c. Egg; d. Larva; e. Pupa; f. Normal and injured corn plants; g. Larva in retreat burrow; h. Larva entering plant' i. Pupa in pupal cell; j. Injury to *Spartina*.

The Biology of the Four-Lined Borer,*

Luperina stipata (Morr.)

By George C. Decker

Since the introduction of the European corn borer (*Pyrausta nubilalis* Hubn.) into the United States there has been an increased interest in all insects which have the habit of boring in plants, especially corn. Many of our native stalk borers, heretofore little known in literature but frequently of considerable local importance, are now receiving some measure of attention. Because the four-lined borer, *Luperina stipata* (Morr.), was found to be a corn pest of considerable importance its life history and habits were studied by the writer during the three-year period from 1927 to 1929.

ECONOMIC HISTORY

The first reference to the four-lined borer as a pest was made by F. M. Webster (13), who in 1889 reported it as doing serious damage to corn in various parts of Indiana, especially on low, recently drained and newly broken land. A year later (referring to his note of 1889) he wrote, "Since that notice was written, reports of serious depredations have come to me from Clinton, Miami, Madison and Johnson Counties, Indiana, all indicating that this is the most destructive of all cutworms in the localities where it occurs; some fields being totally ruined, and that, too, after it is too late in the season for replanting. Both low and high lands, timothy and clover sod seem alike attacked, even though the ground may have borne but one previous crop of grass or clover." Aside from these early reports by Webster there is little in literature concerning outbreaks of this species. Forbes (5) in his monograph on corn insects mentions the occurrence of the larva in Illinois, but he says nothing concerning its economic importance in the state.

On June 18, 1927, the writer, accompanied by Dr. C. J. Drake, visited the Cris Teig farm near Randall, Iowa, where the borer was found working in a field of corn. Most of the damage was confined to a low area near a prairie meadow which extended along one side of the field. On July 14, 1927, several specimens

*The writer is indebted to Dr. C. J. Drake and other members of the entomology staff of Iowa State College for their many helpful suggestions; to Messrs. R. A. Cushman, J. M. Aldrich, H. J. Reinhard and J. C. Gilman, for determining the species of parasites; to Dr. L. H. Pammel and Miss C. M. King for identifying host plants; to Mr. A. Janson for preparation of the plates used in this paper; and to Messrs. Randall Latta and T. S. Hsiung for assistance in the field and in the laboratory.

were received from Kossuth county where the borer was doing considerable damage in two corn fields. These infestations also occurred in fields adjacent to areas of natural prairie sod.

In 1928 and again in 1929 the borer reappeared at Randall and also in several counties in the northern part of the state. From one-half to two and one-half acres of corn were destroyed in each of the seven largest infestations examined. Most of the infestations, however, were small and only a few rows of corn along the margins of the fields were seriously injured. It would be difficult to estimate the total loss resulting from the numerous small infestations of this type.

DISTRIBUTION

Luperina stipata is a North American species and is generally distributed over the northeastern portion of the United States and part of Canada. It is definitely reported as occurring in New Brunswick, Maine, Massachusetts, New York, Ohio, Indiana, Illinois, Wisconsin, Minnesota, Iowa and Colorado. The adult moths are quite rare in collections, due to the fact that they are infrequently attracted to lights and are very adept at concealment in the field. Hence, it is not improbable that this species occurs in regions outside of its present known range.

The borer is found thruout Iowa, but it is much more common in the north-central portion. The Iowa records are given in fig. 3.

HOST PLANTS

Field observations indicate that the common slough grass (*Spartina michauxiana* Hitchs.) is its natural host plant, as it is the only plant in which the borer has been consistently found. In the north-central part of the state practically every stand of *Spartina* of five square yards or larger was infested, and it might be added that nearly every one of the numerous small

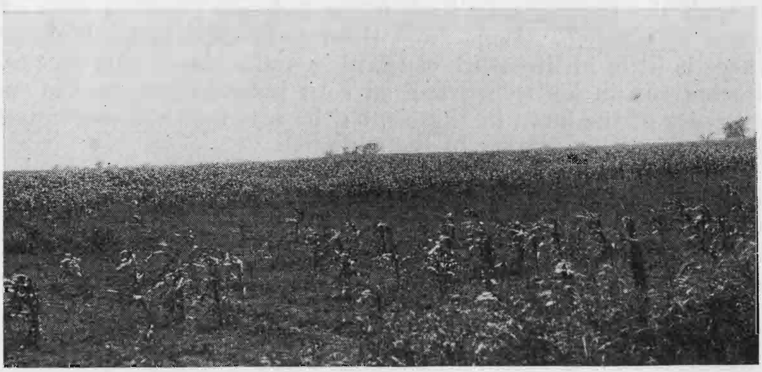

Fig. 2. A field of corn seriously damaged by the four-lined borer, *Luperina stipata* (Morr.).

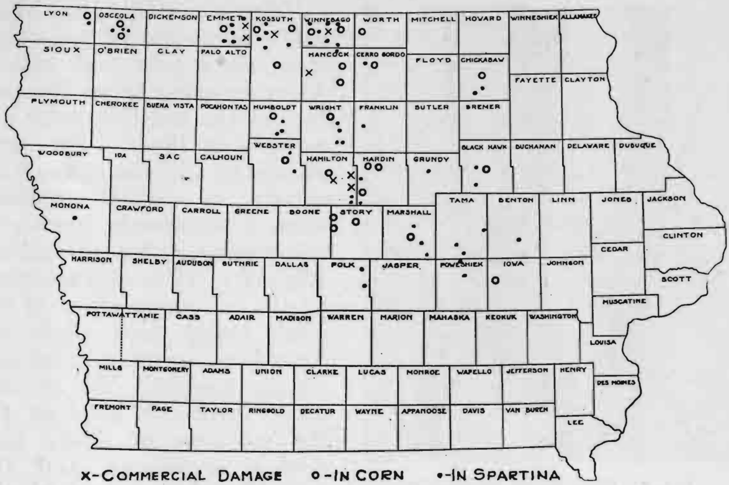

Fig. 3. Distribution of the four-lined borer, *Luperina stipata* (Morr.), in Iowa.

patches growing along fence rows was also infested. Very young borers have been taken in timothy (*Phleum pratense* L.), wild rye (*Elymus robustus* Scribn. and J. G. Sm.), sedge (*Carex sp.*), oats (*Avena sativa* L.) and corn (*Zea mays* L.). A few half-grown larvae were found feeding in the crowns of green foxtail (*Setaria viridis* L.) and Mexican dropseed (*Muhlenbergia mexicana* L. Trin.). Corn is apparently the only cultivated plant that is commercially injured by the borer and so far as known is the only plant other than *Spartina* in which the borer readily matures.

NATURE OF INJURY

The larva attacks its host in several different ways. On tender young plants the newly hatched larvae usually bore into the stem near the surface of the soil or crawl under the lowest leaf sheath and enter at that point. On larger and tougher plants they frequently climb up the plant and tunnel down into the "open heart." If the soil is loose or if there is a crevice in the ground near the plant, the borer frequently tunnels into the stem below the surface and just above the crown (fig. 4). Upon the death of their initial host, first, second and third instar larvae may enter a second host by one of the above mentioned ways. As the borers become older and larger the tendency to work below the surface of the soil prevails. Borers in the fourth and later instars invariably descend to the bottom of their burrows and then migrate underground to other plants. In this way a single borer sometimes destroys every plant in a hill of corn without coming to the surface of the soil.

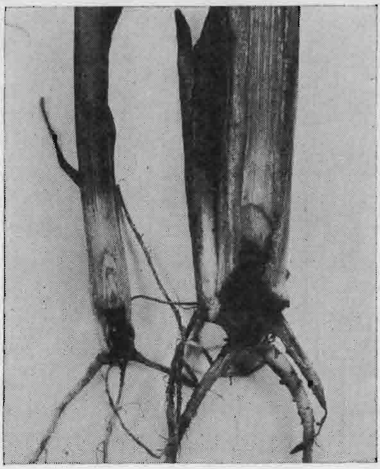

Fig. 4. Corn plants showing charact eristic injury produced by the borer.

Corn is usually attacked by half-grown larvae migrating from from wild host plants. After entering below the surface of the soil they bore upward thru the "heart" and ultimately kill the plant. This mode of attack produces what is commonly known to the grower as "dead heart." (fig. 1f.) It is characterized by the central portion of the plant being dead while the outer leaves remain green and appear healthy. The tunnels form favorable avenues for the entrance of decay producing organisms, and the complete destruction of the plant is only a matter of a few days.

COMPARISON OF INJURY WITH THAT PRODUCED BY OTHER BORERS

Several species of insects are more or less commonly found to attack corn in such a way that the injury might easily be confused with that of the four-lined borer. The stalk borers, *Papaipema nebris* (Gn.) and *P. cataphracta* (Grote); the spindle worm, *Achatodes zea* (Harris); the lined corn borer, *Oligia fractilinea* Grote; the pale western cutworm, *Porosagrotis orthogonia* Morr.; the hop-vine borer, *Hydroecia immanis* Gn.; wire worms, *Melanotus spp.*, and several other insects frequently cause "dead heart" in corn. The injuries produced by these insects may be so much alike that only a trained observer can distinguish them. The final determination, of course, frequently rests in the finding of borers.

The species most apt to be confused with *Luperina stipata* is the stalk borer (*Papaipema nebris*). The larva of the latter (fig. 5) is white, marked with four longitudinal purplish brown stripes and a broad band of the same color around the middle of the body. It enters the plant above the soil line, and by burrowing upwards it destroys the central portion of the plant. It seldom works in that portion of the plant which is below

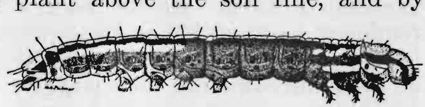

Fig. 5. Young caterpillar of the common stalk borer (*Papaipema nebris*).

the ground. In general appearance and method of attack *P. cataphracta* is very similar to this species.

The larva of the pale western cutworm is a dull, gray or greenish caterpillar, rather inconspicuously marked with fine greenish or greenish brown longitudinal stripes. This species almost invariably attacks the plant below the surface of the soil, and when not actually feeding the larva is usually to be found in the soil some few inches away from the plant. Ordinarily this species will be found on high, light soils, while the four lined-borer will be found on heavier lowland soils.

The larva of the spindle worm (*Achatodes zea*) is yellowish-white with head, thoracic and anal shields, glossy-black; each body segment is adorned with 12 to 14 prominent black tubercles. This species is common in elder-berry and occasionally attacks corn and other plants growing in close proximity. Injury to corn is very similar to that produced by *Papaipema nebris.*

The lined corn borer (*Oligia fractilinea*) and the hop-vine borer (*Hydroecia immanis*) are not often encountered in corn in Iowa. The former prefers to enter the "heart" of the plant from above, while the latter usually enters near the ground and burrows upward in the stem.

Wireworms (*Melanotus* and other genera) occasionally burrow into the side of the stem and kill the young corn plants. Several other species of insects, such as cutworms, sod webworms, seed corn maggots, aphids and white-grubs, which work on the roots may kill the plant; but in these cases the whole plant wilts and dies, and such injury would not be confused with "dead heart."

Mention should be made of mechanical injury not because it resembles injury by the borer but rather because borer injury may be overlooked and passed as mechanical injury. (By mechanical injury is meant injury due to machines, wind or weather.) Very often infestations at the edge of the field go unobserved, and all of the damage is attributed to injuries resulting from cultural operations.

SYSTEMATIC HISTORY AND SYNONYMY

1875 *Hadena stipata* Morrison. Proc. Acad. Nat. Sci. of Philadelphia, **XXVII**, p. 64.
1889 *Hadena stipata* Webster. Insect Life. **II**, p. 132
1890 *Hadena stipata* Webster. Insect Life. **II**, p. 382
1890 *Luperina stipata* Smith. U. S. Nat. Mus., **XIII**, p. 411
1890 *Luperina* (*Hadena*) *stipata* Webster. Bul. U. S. D. A. Bur. Ent. 22, p. 47.
1893 *Luperina stipata* Smith. Bul. U. S. Nat. Mus. 44, p. 131.
1894 *Hadena stipata* Webster. Insect Life. **VI**, p. 146.
1901 *Hadena stipata* Beutenmuller. Bul. Am. Mus. Nat. Hist. **XIV**, p. 301.

1902 *Hadena stipata* Dyar. Bul. U. S. Nat. Mus., 52, p. 53.
1905 *Hadena stipata* Forbes. 23rd Rept. of State Entomologist of Ill., p. 77.
1908 *Luperina stipata* Hampson. Cat. Lepid. Phal. **VII**, p. 468
1916 *Luperina stipata* Barnes & McDunnough. Check list Lepid. N. Am., p. 63.

This species was described by H. K. Morrison (9) in 1875, as *Hadena stipata*, from a specimen sent to him by Mr. Thomas E. Bean of Illinois. Fifteen years later Smith (11) transferred *stipata* to the genus *Luperina*. Since that time *stipata* has been frequently changed from one genus to the other, due to the fact that differences of opinion as to generic types have led to considerable confusion in these and certain other noctuid genera. Recent workers, Hampson, Barnes, McDunnough and Heinrick, however, are agreed that *stipata* should be placed in the genus *Luperina*.

COMMON NAME

Webster (14 and 15) has referred to this species as a cutworm, and Forbes (5) mentions it with other species of the genus under the caption "The Hadena Stalk Borers," but so far as the writer can find no specific common name has been applied to it. In as much as this insect is most frequently found as a characteristically striped, boring caterpillar it may be appropriately called the "four-lined borer."

DESCRIPTIONS

EGG

(Fig. 1., c.)

Oblate-spheroidal, circular in cross section, pearly white when laid but soon turning yellowish gray or pinkish; exochorion sculptured with approximately one hundred raised, longitudinal ridges; converging of ridges produces reticulated area around poles; micropyle located in the center of one flattened pole surrounded by rosette of pyreform cells.

Equatorial diameter .625 mm.; polar diameter .450 mm.

LARVA

First to fifth instars.

Head flattened, circular to obovate in outline, yellow with smoky shading; trophi brown; ocelli conspicuous, black, six on each side. Body moderately slender, cylindrical tapering toward both extremities, except in newly hatched and recently molted individuals, which taper gradually from head to anal extremity. Thoracic shield broad, undivided, smoky yellow to fuscous, darker near the cephalic and lateral margins; anal shield smoky yellow, darker near margins, with five spines on the caudal margin. Legs and prolegs normal (however, young larvae frequently move with a looping movement similar to that of geometrid larvae); spiracles with dark brown or black borders and pale centers; eighth abdominal spiracle larger and higher than the others. Newly hatched larvae pale yellowish white, slightly dusky caudad, often with a pinkish or greenish tinge. Characteristic color pattern evident in all instars. Ground color of body yellowish white; body segments from mesothoracic to the ninth abdominal inclusive marked with four broad, reddish-brown, longitudinal stripes; two subdorsal stripes separated by a narrow dorsomedian line of yellowish-white; a broad irregular, somewhat broken and apparently double, lateral stripe on each side just above the spiracles; also a light, double sublateral stripe, extending from the first to the ninth abdominal segments just above the base of the prolegs; ventral surface yellowish white.

Head capsule measurements for each instar are shown in table I.

TABLE I. LARVAL HEAD CAPSULE, WIDTHS IN MM.

	Instars						
	I	II	III	IV	V	VI	VII
Theoretical	.316	.478	.725	1.09	1.66	2.52	
Six instar larvae	.315	.470	.720	1.10	1.65	2.42	
Seven instar larvae	.315	.469	.718	1.07	1.57	2.04	.58

Sixth instar (fig. 1. d.)

Head rounded, slightly bilobed, quadrate to obovate in outline, yellowish, faintly mottled with fuscous; trophi brown; ocelli, six on each side, black, III, IV and V larger than I, II and VI (fig. 6). Epistoma with normal setae (E^1, E^2); the distance between E^2 on either side more than twice that between E^1 and E^2. Frontal punctures (F^a) very close together and immediately between frontal setae (F^1), near lower margin of frons. The distance between F^1 and Adf^1 greater than the distance between Adf^1 and Adf^2; Adf^2 well behind beginning of LR. Adfrontal puncture (Adf^a) slightly anterior to beginning of LR; closer to Adf^2 than to Adf^1. Anterior setae (A^1, A^2 and A^3) forming a slightly obtuse angle; A^2 short, about equidistant from A^1 and A^3; A^1 and A^3 long. Anterior puncture (A^a) equidistant from, and slightly above a line connecting A^2 and A^3. Posterior setae (P^1, P^2) long; P^1 laterad and slightly posterior of Adf^2; P^2 posterior to P^1; the distance between P^1 and P^2 equal to the distance between P^1 and Adf^2; a line connecting P^1 and P^2 approximately parallel to LR. Posterior punctures two; P^a nearer to L^1 than to any other seta, lying between L^1 and Adf^2; P^b close to and slightly latero-ventrad of P^2. Lateral seta (L^1)

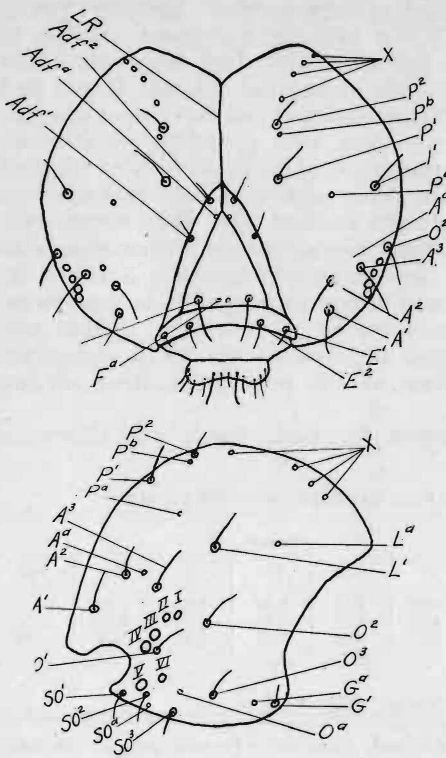

Fig. 6. Head capsule of six instar larva showing setal arrangement: above, dorsal view; below, lateral view.

remote from P^1 and A^3 with which it forms a right triangle, L^1P^1 being perpendicular to L^1A^3. Lateral punctures (L^a) remote postero-ventrad of L^1. Ocellar setae (O^1, O^2, O^3) well separated; arranged in the form of an isosceles triangle (O^1O^3 being equal to O^2O^3); O^1 ventrad of ocellus IV; O^2 postero-ventrad of ocellus I; O^3 remote, postero-ventrad of ocellus VI. Ocellar puncture (O^a) lying between O^3 and ocellus V but nearer to the seta than to the ocellus. Genal seta (G^1) remote, postero-ventrad of O^3. Genal puncture (G^a) antero-dorsad of G^1. Subocellar setae (SO^1, SO^2, SO^3) triangularly placed, SO^2 very close to ocellus V. Subocellar puncture (SO^a) equidistant between SO^1 and SO^3.

Body cylindrical, moderately stout, tapering towards both extremities, without secondary hairs, dirty white in color, with characteristic color markings of earlier instars only faintly discernible; legs and prolegs normal. Chrochets uniordinal and arranged in a mesoseries. Prothoracic shield broad, undivided, yellowish, more or less smoky, with small area of pigmented granules between I^b and II^b. Spiracles oval, black with brown centers; eighth abdominal spiracle slightly larger and higher than the others. Anal plate yellowish with five reddish brown spines on its posterior margin. Body setae pale yellow to amber, moderately long; tubercles inconspicuous, not strongly chitinized. (fig. 7.)

Prothorax: I^a, I^b, II^a, II^b and II^c on the shield; the two former on the cephalic margin, the three latter on the caudal margin; I^c absent (or I^c may be represented by the puncture

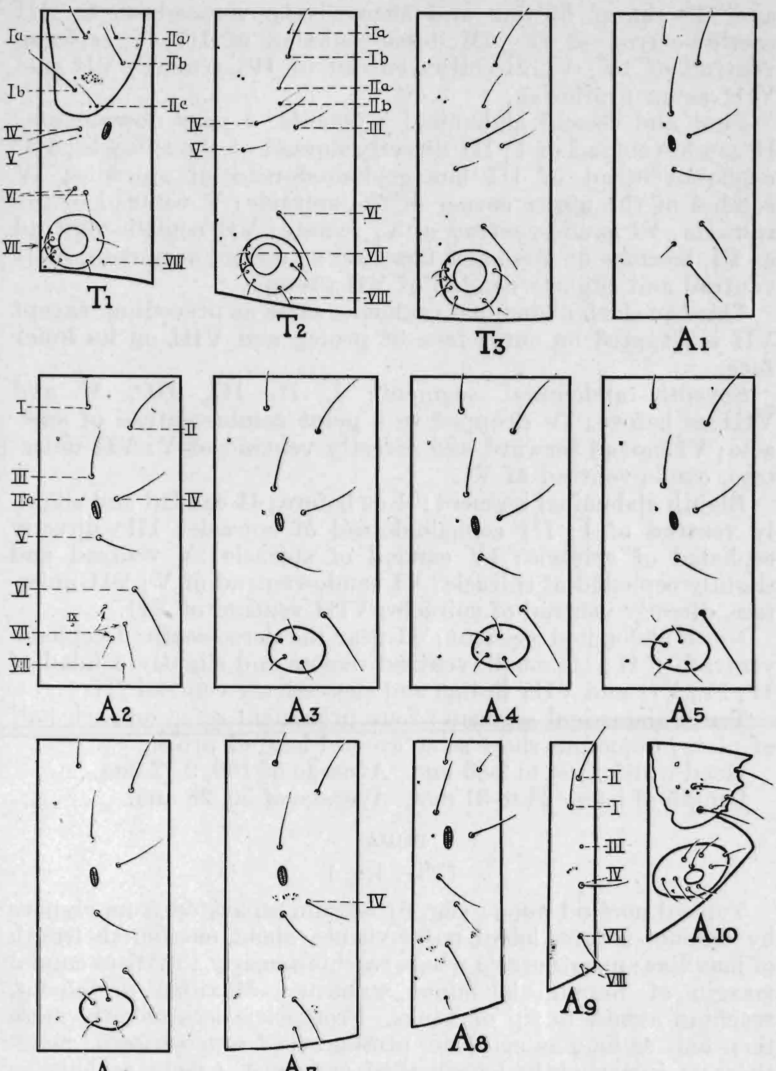

Fig. 7. Setal pattern of mature larva of *Luperina stipata*.

on the shield close to II^c); IV and V approximate and on a single chitinization cephalad of the spiracle; VI bisetose, ventrad of IV and V; VII represented by a number of setae at the base of the leg; VIII caudo-ventrad of the leg.

Mesothorax and metathorax: I^a near the dorsomeson, I^b, II^a

and II^b almost in line and successively ventrad of I^a; III caudo-ventrad of II^b; IV dorso-cephalad of III; V cephalo-ventrad of IV; VI directly ventrad of II^b, remote; VII and VIII as on prothorax.

First and second abdominal segments: I near dorsomeson; II caudo-ventrad of I; III directly dorsad of the spiracle; III^a cephalo-ventrad of III but cephalo-dorsad of spiracle; IV caudad of the upper corner of the spiracle; V ventrad of the spiracle; VI caudo-ventrad of V, remote; VII cephalo-ventrad of VI, bisetose on first and trisetose on second segments; VIII ventrad and slightly caudad of VII group.

Third to sixth abdominal segments same as preceding, except VII is situated on outer face of proleg and VIII on its inner face.

Seventh abdominal segment: I, II, III, III^a, V and VIII as before; IV dropped to a point caudo-ventrad of spiracle; VI moved forward and directly ventrad of V; VII unisetose, caudo-ventrad of VI.

Eighth abdominal segment: I as before; II caudad and slightly ventrad of I; III cephalo-dorsad of spiracle; III^a directly cephalad of spiracle; IV caudad of spiracle; V ventrad and slightly cephalad of spiracle; VI caudo-ventrad of V; VII unisetose, directly ventrad of spiracle; VIII ventrad of VII.

Ninth abdominal segment: II near the dorsomesan; I cephalo-ventrad of II; III small, ventrad remote and slightly caudad of II; IV, VII and VIII in line and successively ventrad III.

Tenth abdominal segment: four prominent setae on each half of plate; numerous short setae around base of proleg.

Head width, 2.24 to 2.80 mm. Average of 100, 2.52 mm.

Length of body, 23 to 31 mm. Average of 50, 28 mm.

PUPA

(Fig. 1, e.)

Typical noctuid pupa; (fig. 8) labrum separated from clypeus by distinct suture, labial palpi visible, about one-fourth length of maxillae; mesothoracic wings reaching nearly to ventro-caudal margin of fourth abdominal segment. Maxillae prominent, reaching almost to tip of wings. Prothoricic legs slightly more than half as long as maxillae, prothoracic femur exposed; mesothoracic legs slightly longer than antennae, nearly as long as maxillae; metothoracic legs exposed caudad of maxillae, extending to tip of wings. Abdominal segments gradually tapering; dorso-cephalic margins of abdominal segments four, five, six and seven marked with many small, chitinized, circular pits; pit markings extending to ventral surface of segments five, six and seven but fewer in number and less prominent; spiracles (except eighth abdominal)ellipsoidal, dark brown; eighth abdominal

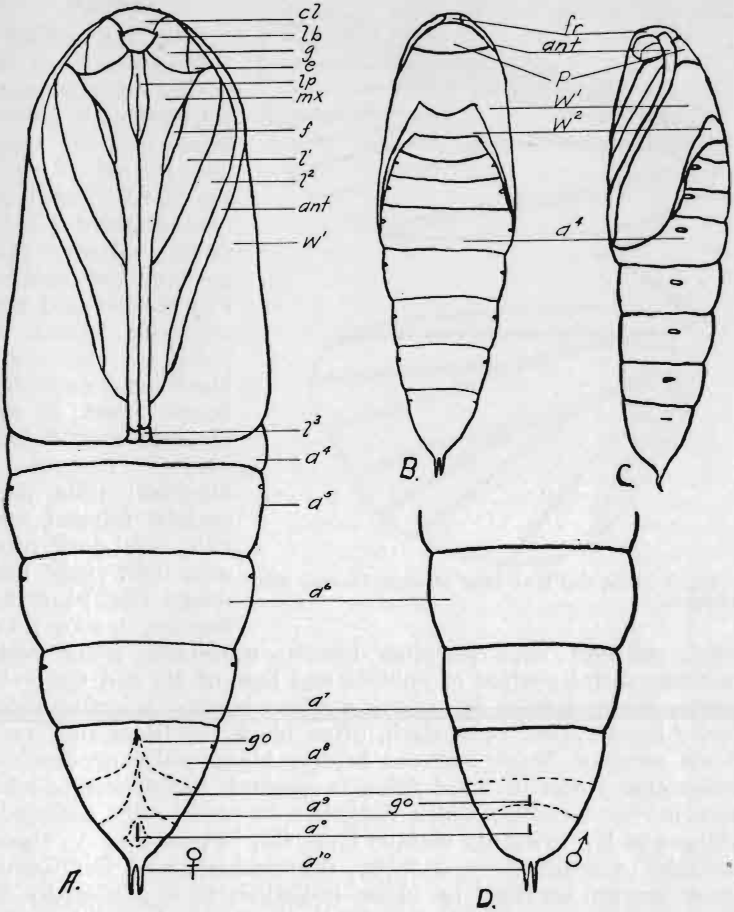

Fig. 8. Pupa of four-lined borer: A, ventral view of a female; B, dorsal view; C, lateral view; D, ventral view of the abdominal segments of a male.

spiracle reduced to slit-like opening; proleg scars absent; larval setae and setal arrangement largely retained; cremaster short, ending in two straight (or slightly curved) sharp spines; color varying from very light to dark brown (according to age); genital opening of female simple, slit-like, cephalad of eighth abdominal spiracle, cephalic margins of segments nine and ten curved forward towards genital opening; genital opening of male simple, slit-like, on a slight elevation, caudad of eighth abdominal spiracle, on ventro-caudal margin of ninth abdominal segment.

Length 18 to 23 mm.; greatest width 6 to 7 mm.

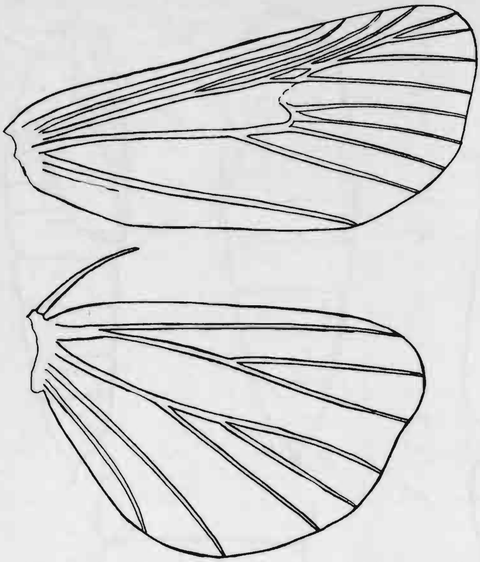

Fig. 9. Fore and hind wing of adult, showing wing venation.

ADULT

(Fig. 1, a and b.)

Female: Head and thorax ocherous gray, suffused with fuscous brown; eyes large, rounded; frons smooth; palpi upturned, third joint short, oblique, sides more or less blackish. Prothoracic and metathoracic crests divided, a transverse black band extending across front of prothoracic crest. Legs grayish fuscous to blackish; tibia moderately fringed with hair, tarsi dark, often with light rings. Fore wings (fig. 9) rather narrow, pale fuscous, suffused with purplish brown, especially along costal margin; distal portion of cubitus and base of M_3 and Cu_1 veins white, black defined by ochreous white beyond transverse posterior band; other veins dark, often black; subbasal and transverse anterior bands reduced to few black scales or obsolete; transverse posterior band faint to obscure, indistinctly double, margins black, center white, indistinct in radial cells, outwardly oblique to M_3, inwardly oblique from Cu_1 to near 2nd A., thence straight or indefinite to margin; subterminal band faint, white inner margin outlined by black, indistinct to M_3, inwardly oblique from Cu_1 to center of Cu_2 cell, then curved slightly out to meet 2nd A. at margin; terminal line represented by a series of black lunules between veins; claviform replaced by broad black fascia in Cu cell from t. a. to t. p.; obicular small, irregular, defined by black, absent in some specimens; reniform small, upright, irregular, light to fuscous center outlined by black, rests at union of M_3 and Cu_1 veins, sinuous black streak below base of cell; undulating black streak in cell A_2, before t. a.; terminal space dark fuscous; triangular black area covering M_3 cell and distal portions of M_1 and R_5 cells. Hind wing dirty white. slightly darker near tremen; underside of both wings dirty white irrorated with brown; abdomen dirty white tinged with brown towards extremity, lateral fringe of hairs but no distinct lateral tufts.

Male: Similar to female, usually slightly lighter in color. Antennae ciliated, the anal tuft more or less bushy or fan shaped. Expanse, 28 to 40 mm.

METHODS

The life history studies and experiments with the four-lined borer were conducted largely at Ames, Iowa, in a screened outdoor laboratory.

Larvae were reared individually in shell vials and stender dishes. Thirteen by sixty mm. shell vials with cotton plugs were used for the first three instars, and sixty by thirty-five mm. stender dishes or three ounce crystal glass ointment jars, were used for the latter instars. Three ounce ointment jars with perforated aluminum tops were found to be most satisfactory for work with the larger caterpillars. Observations were easily made and the perforated lids permitted the free exchange of air preventing the accumulation of moisture and injurious gases. The larvae were examined daily, all molts were recorded and the food changed as needed, which was usually every second day. Larvae were collected in the field at weekly intervals to compare the development in the field with insectary rearing records.

Pupae were placed on moist, fine sand in the same type of ventilated jar as was used for mature larvae.

Shortly after emergence the moths were removed to modified Riley cages where their activities could be observed by placing a red electric light bulb near the side of the cage opposite the observer.

In order to determine the number of eggs laid by individual females, pairs of moths were placed in battery jars containing dead corn and grass leaves. These cages were examined daily and all eggs counted and removed. Other pairs were caged with both living and dead plants. The eggs were not counted until after the moths had died. Egg masses were left attached to the plants on which they were deposited and were kept in the outdoor laboratory during the winter months.

LIFE HISTORY AND HABITS

EGG

The normal length of the egg stage is about eight and one-half or nine months. Eggs which are deposited between July 15 and the last of August do not hatch until the following spring, usually during the latter part of April. Hatching dates for 1928 and 1929 were identical, beginning April 16, and extending to April 30, with a maximum hatch April 22. It appears that the length of the egg stage may be exceedingly variable under different conditions of temperature and humidity.

Development: Some embryological development takes place during the first few days after egg deposition, but in a few days growth ceases and the eggs remain in a partially developed condition until spring or until after a suitable exposure to some reactivating or accelerating agent such as low temperature. Eggs laid July 15 and kept at a temperature of 27°C. and at 80 percent relative humidity did not hatch and at the end of nine months were apparently all dead. Other eggs which were laid the same day but which were later subjected to temperatures below the threshold of development, or minimum effective temperature, for one month or longer developed normally when replaced under conditions favorable to incubation. In this way the length of the egg stage can be shortened from nine months to forty-five days.

LARVA

Newly hatched larvae appear during the latter part of April or the first part of May, which is about the same time that our earliest grasses are sending up their first shoots. During the last week in April, when hatching was at its peak, blue grass, timothy, sedge, Mexican dropseed, wild rye and slough grass were making fair growth while fox tail and some of the other grasses had not started. This would indicate that the young larva fed for a time on some of these early grasses.

General Habits: Hatching may occur at any time of the day or night, but as a rule larvae hatching during the day remain concealed under a leaf sheath or in some other suitable place until evening before starting to search for food. In some instances the larvae devour the shells from which they have issued and a few have also been observed to eat parts of dead stems and leaves, but the majority do not feed until they have found fresh green plants. When a suitable plant is found very hungry individuals will begin at once to eat the epidermis of the leaves, whereas others will crawl about and explore one or more plants before settling down to feed. Usually only one borer can be found in a plant. As has been mentioned in discussing the nature of injury, larvae may attack young plants by one of three different methods. The initial host may be killed in two or three days, or the plant may be large enough to survive for a week, but in any case as soon as a plant is killed the larva migrates to another plant. Larvae in the first four instars may move about above ground more or less freely, but those in one of the last three instars always enter the plant below the surface of the ground. The latter usually construct an elongated tube or tunnel just beneath the surface of the ground, which extends from the entrance hole to a point two or three inches from the plant. When not feeding the larva usually will be found resting in this retreat. Excrement and castings from the feeding burrow in the plant are packed into the far end of this underground tunnel, and if it becomes nearly filled a side branch or a new tunnel is formed.

The ability of the newly hatched larvae to withstand adverse conditions is remarkable. Larvae die and shrivel quite rapidly at high temperatures especially when they are accompanied by low humidities, but since hatching occurs at a time when these conditions are not prevalent, newly hatched larvae have been known to live without food for from 48 to 72 hours, during most of which time they were active and crawling about in their cages. The fact that first instar larvae which were left out-of-doors when the temperature dropped to 26°F. were not injured, and the fact that young larvae feeding on grass and corn developed normally though subjected to freezing temperatures on several successive nights, led to further studies on the effects of low temperatures such as might occur during late April. Newly hatched larvae unfed and kept at 11°C. lived for from 2 to 15 days, others kept at 0°C. lived for from 8 to 37 days, and still another lot kept at low temperatures which varied between 0 and —16°C. lived for from 2 to 30 days. Second instar larvae which were almost ready to molt were subjected to the same tests and found to be almost as hardy as the unfed individuals. The results of these experiments are summarized in table II.

During the course of these experiments it was noted that the larvae became very sluggish at temperatures below 8°C. and that they became inactive at 5°C.

Newly hatched and unfed larvae react positively to light and negatively to the force of gravity. After they reach their host plants these reactions are not so noticeable, and as the larvae become older they are practically reversed.

Ecdysis: Several days after hatching when the larva has increased in length by about 50 percent, it stops feeding and becomes more or less inactive. A prominent, white, swollen area which appears between the head and the prothorax continues to enlarge until the outer cuticle ruptures. Then by a series of violent contractions the old "skin" is worked back over the body and the old head capsule is moved forward off of the head. This is the first molt and the end of the first stadium.

TABLE II. SHOWING THE EFFECT OF LOW TEMPERATURE ON THE LENGTH OF LIFE OF NEWLY HATCHED AND SECOND INSTAR LARVAE.

Temperature in° Centigrade scale	Number of days						
	Newly hatched larvae				Late 2nd instar larvae		
	−16* to 0	0	11	15	−16* to 0	0	11
Minimum	2	8	2	1	1	5	1
Maximum	30	37	15	5	20	35	9
Average	18	26.3	10.7	2.7	7.4	24	7.2
Number of specimens	25	100	100	75	10	25	20

*Temperature fluctuating between 0 and − 16° C.

Instars: Altho subject to considerable variation the number of instars characteristic of this species is apparently six. However, larvae having more than six instars are quite common. When the rate of growth is reduced by abnormal temperatures, poor food or other unfavorable conditions the larvae continue molting at regular intervals with little or no increase in size, and in extreme cases there may be a slight reduction in size. The larvae of one series which were purposely given poor food had from seven to eleven molts, and about one-third of them never reached the pupal stage but died after they had molted eight or nine times. During the 1929 season the following experiments were conducted to determine the effects of using various parts of the corn plant as food for the larvae. In each case 25 larvae were used.

Experiment

A. Larvae were fed basal portion of rapidly growing young corn plants.

B. Food as in experiment A.

C. Larvae were fed middle portion of stalk from rapidly growing young corn plants.

D. Food as in experiment C.

E. Larvae were fed the upper portion of the stalk of rapidly growing young corn plants. (This portion consists largely of closely rolled leaves.)

F. Food as in experiment E.

G. Larvae were fed leaves from rapidly growing young corn plants. (Part fed was taken from leaf blade 2 to 4 inches above rolled portion at base.)

H. Larvae were fed basal portion of stalk from corn in tassel. (Stalk was somewhat woody.)

I. Larvae were fed basal portion of stalk from corn setting ears. (Stalk was quite woody.)

It was found that the larvae which were fed succulent stalks of young corn made more rapid growth and completed their development with a smaller number of instars than the larvae which received less desirable food. A and B produced a predominance of six-instar individuals with a few larvae having seven instars.

C and D produced only seven-instar individuals.

E and F produced a few seven-instar individuals but the majority required eight instars.

G. All of these larvae died in or before the ninth instar.

H and I produced individuals having nine or ten instars and six individuals died in the eleventh instar.

The results of these experiments are presented graphically in fig. 10.

A study of table I reveals that the head capsule measurements of the six-instar individuals are in close agreement with

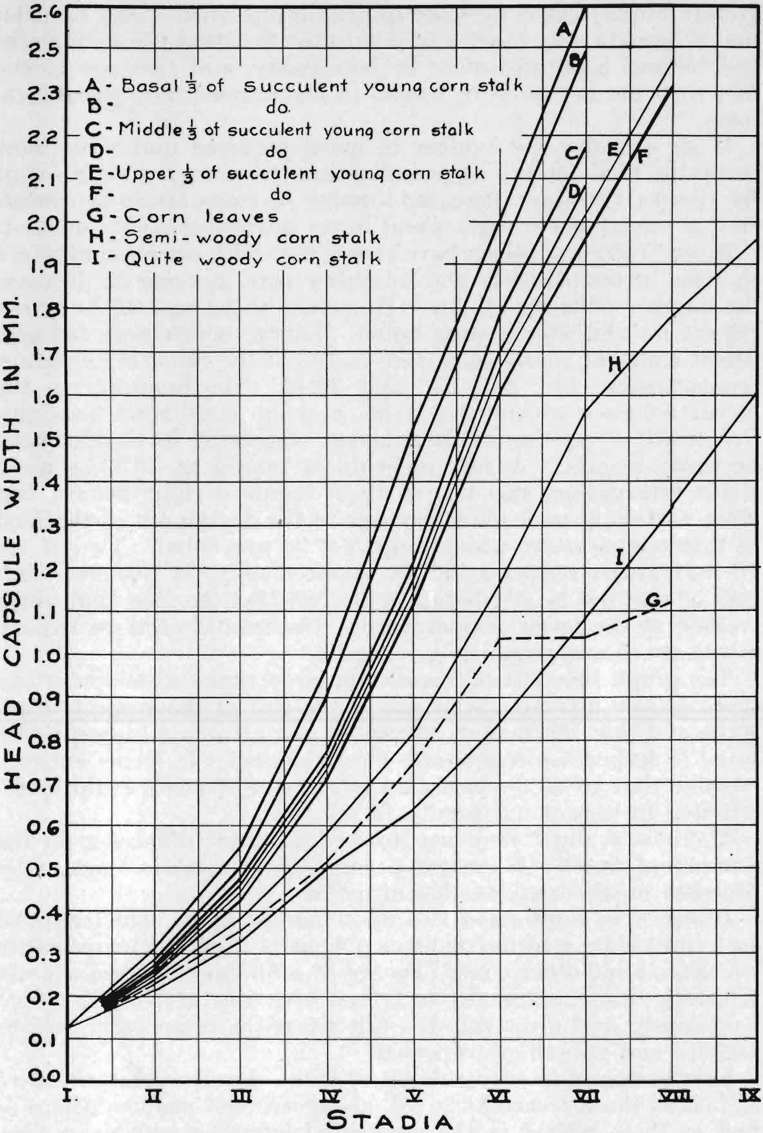

Fig. 10. Showing the effect of food (using various parts of a corn plant as a food) upon the width of successive head capsules.

the theoretical dimensions calculated by the application of Dyar's law. (3). It should be further noted that measurements for the seven instar individuals are in close agreement with the others up to the fifth molt, where the normal rate of increase is greatly reduced as if by some retarding influence. This retardation of growth may have been due to the fact that the corn stalks had become hard and more or less woody, and also due to the fact that the larvae were forced to make more frequent migrations.

If we consider the number of molts required under the most favorable food conditions as indicating the normal tendencies of the species, then any increased number of molts are to be considered as variations brought about by an unfavorable environment.

Ripley (10) and others have shown that with some *Lepidoptera* changes in temperature and humidity may increase or decrease the number of molts by one. However, in the case of *Luperina stipata* no such effects were noted. Larvae which were fed succulent stalks of young corn were reared at the following constant temperatures: 13°, 23°, 27° and 33°C. The humidity in the larval burrows within the stalks may be considered constant. Practically every one of these larvae completed its development in seven instars. A few individuals reared at 33°C. showed slight retardation, and two of them required eight instars, but these variations were obviously due to the drying out of the food at that temperature, which could not be prevented. Two of the 45 individuals reared at 13°C. required only six instars. This may or may not be attributed to the fact that the food kept much fresher at the lower temperature. The results of these experiments are shown graphically in fig. 11.

The graph shows that despite the large range of temperatures there are no marked variations in the size of the respective instars, and that the various curves are not arranged consecutively so as to indicate a temperature relationship. It seems entirely possible that all of the variation in number of molts could be attributed to lack of uniformity in the food.

There is a slight tendency toward a sexual difference in the number of molts A greater percentage of females than males presents an increased number of molts.

Duration of Stadia and Length of Larval Life: The length of each individual stadium depends primarily upon the temperature while food and other conditions are of secondary importance. At relatively high temperatures larvae are very active, they feed voraciously and grow rapidly, but when the temperature drops activity and growth are retarded.

Larvae reared in an incubator at 27°C. developed almost twice as fast as those reared at 20°C., about two and one-half times as fast as those reared in the screened laboratory and about four times as fast as those reared at 13°C. A graphic presentation of these facts is given in fig. 12. The curves presented show that there is a marked uniformity in the proportionate length of the respective stadia, and that the length of any particular stadium is a variable which is directly correlated with variations in

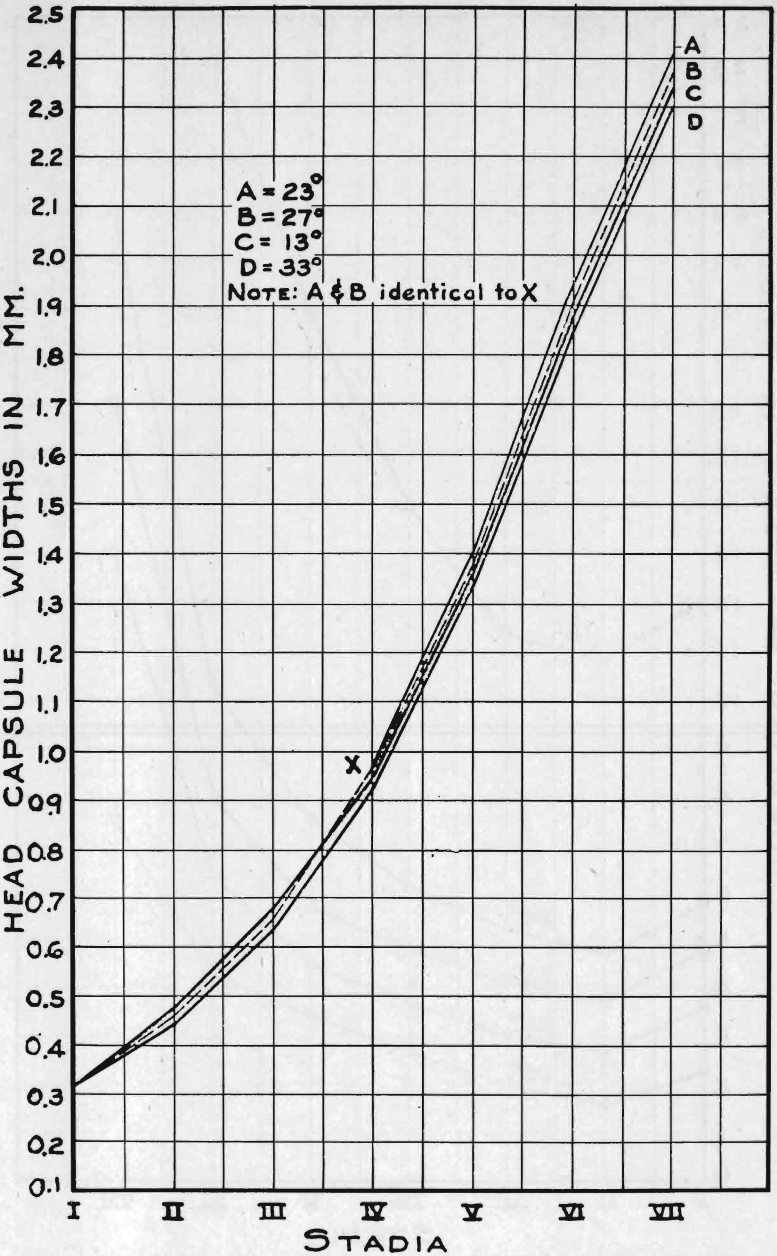

Fig. 11. The effect of temperature upon the width of successive larval head capsules.

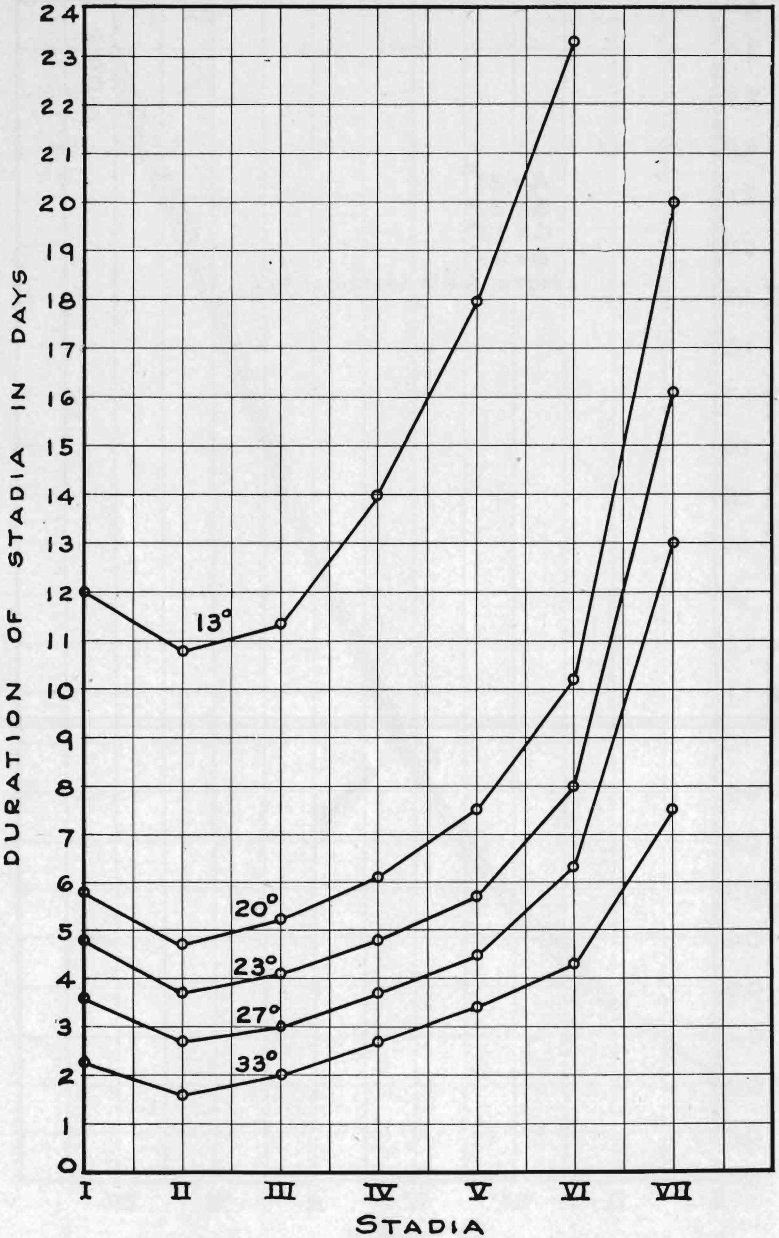

Fig. 12. Effect of temperature upon the duration of the larval stadia.

TABLE III. DEVELOPMENT OF SIX INSTAR LARVAE IN SCREENED INSECTARY

1928	Number of days in each stadium						Total days in larval stage
	I	II	III	IV	V	VI	
Minimum	8	5	6	7	13	18	70
Maximum	17	8	8	11	23	28	78
Average	12	6.5	6.5	9	19	24	75
Specimens	39	39	39	39	39	39	39
1929							
Minimum	13	6	7	6	11	14	68
Maximum	17	10	11	10	19	21	79
Average	14	8.5	9.5	8.0	15	17	72
Specimens	37	37	37	37	37	37	37

TABLE IV. DEVELOPMENT OF SEVEN INSTAR LARVAE IN SCREENED INSECTARY.

1928	Number of days in each stadium							Total day in larval stage
	I	II	III	IV	V	VI	VII	
Minimum	9	5	5	7	10	9	20	78
Maximum	17	8	9	14	14	13	26	88
Average	12	6.5	6.5	9.2	12	10.5	24	81
Specimens	44	44	44	44	44	44	44	44
1929								
Minimum	11	6	6	5	7	9	14	72
Maximum	17	10	11	9	12	13	21	82
Average	14	8	9	7	10	11	17	75
Specimens	38	38	38	38	38	38	38	38

TABLE V. DEVELOPMENT OF EIGHT INSTAR LARVAE IN SCREENED INSECTARY.

1928	Number of days in each stadium								Total days in larval stage
	I	II	III	IV	V	VI	VII	VIII	
Minimum	10	5	5	7	9	8	9	17	82
Maximum	16	8	9	13	13	13	15	24	96
Average	12	6.5	6	9.5	11.5	11	12	20	88
Specimens	11	11	11	11	11	11	11	11	11
1929									
Minimum	12	5	6	5	8	8	8	13	80
Maximum	16	9	11	11	12	11	14	23	93
Average	14	8	9	7.5	10	9	11	18	86
Specimens	7	7	7	7	7	7	7	7	7

temperature. Figure 12 also shows, as do tables VI, VII and VIII that the second stadium is shorter than the first, and the stadia after the second become successively longer up to the seventh, which is the longest, except in individuals having more than seven molts, in which case the seventh stadium is shortened and the last stadium becomes the longest. Under natural field conditions as shown in tables III, IV and V this uniformity of development may be overshadowed by variations in temperature. In 1928 the mean temperature for May was 2.5°F. above normal while the mean temperature for June was 4.8°F. below normal. As a result the second and third stadia were abnormally short and the fourth and sixth stadia were abnormally long. In 1929 the conditions were reversed. The mean temperature for May was 2.4°F. below normal(4.9° lower than 1928) while the mean temperature for June was only 1.7°F. below normal (3.1° higher than in 1928). As a result the early stadia were lengthened and later stadia shortened. Furthermore the occurrence of warm and cool periods materially affected the length of individual stadia, eg., V and VI in table IV.

Variable or alternating temperatures tend to increase the rate of larval development. Two lots of larvae which were alternately exposed for 8 hours at 13°C. and 16 hours at 27°C. and two additional lots alternately exposed for 16 hours at 13°C. and 8 hours at 27°C. passed thru each of their respective instars and completed their larval development in approximately 89 percent of the estimated time. Table IX, showing the comparative rates of development, is figured upon the basis of the first five stadia to avoid complications arising from the subsequent variability in the number of molts and length of stadia. It might be stated,

TABLE VI. DEVELOPMENT OF SIX INSTAR LARVAE AT 27° C.

	Number of days in each stadium						Total
	I	II	III	IV	V	VI	
Minimum	3	2	2	2	4	12	29
Maximum	4	5	4	5	12	19	34
Average	3.6	2.5	3	3.8	7.0	13	31
Specimens	21	21	21	21	21	21	21

TABLE VII. DEVELOPMENT OF SEVEN INSTAR LARVAE AT 27° C.

	Number of days in each stadium							Total
	I	II	III	IV	V	VI	VII	
Minimum	3	2	2	3	3	5	10	33
Maximum	4	4	4	5	5	8	18	41
Average	3.6	2.5	3.0	3.7	4.5	6.4	13.0	36.6
Specimens	34	34	34	34	34	34	34	34

TABLE VIII. DEVELOPMENT OF EIGHT INSTAR LARVAE AT 27° C.

	Number of days in each stadium								Tota
	I	II	III	IV	V	VI	VII	VIII	
Minimum	3	2	2	3	3	4	6	11	38
Maximum	4	4	4	5	6	7	9	16	45
Average	3.5	2.5	2.1	3.7	4.5	5	7	14	42
Specimens	4	4	4	4	4	4	4	4	4

TABLE IX. SHOWING COMPARATIVE EFFECTS OF CONSTANT AND ALTERNATING TEMPERATURES UPON THE RATE OF LARVAL DEVELOPMENT UP TO THE FIFTH ECDYSIS.

Temperature hours per day at			Time Equivalent days at		Velocity* coef. multiplied by time		Calculated development totals	Actual development totals	Percent increase in rate of development
27°	13°	Total days	27°	13°	27°	13°			
24		17.5	17.5		.9975		.9975	1.000	
	24	66.6		66.6		.9999	.9999	1.000	
8	16	30.9	10.3	20.6	.5871	.3090	.8961	1.000	10.39
16	8	20.5	13.67	6.83	.7791	.1024	.8816	1.000	11.84

*The velocity coefficients (1/T) were: 0.015 at 13° C., and 0.957 at 27° C.

however, that the calculations for each individual stadium and for the total length of larval life for six and seven instar larvae give the same results, i.e., a 10 or 11 percent increase in rate of development in favor of the alternate temperatures.

Evidence that food conditions are of minor importance in determining the length of stadia was discovered in the variable food experiments previously mentioned. It was found that regardless of the type of food or the percent of increase in size as determined by the successive head capsule measurements, the length of the individual stadia remained constant. However, it must be noted that the total length of the larval period may be materially increased by unfavorable food conditions. This is due to the fact that the number of instars required to complete development is increased.

By comparing table III with IV and V and table VI with VII and VIII it may be seen that the larval period is somewhat lengthened as the number of molts is increased. Under field conditions the length of the larval period varies from 68 to 78 days for six-instar larvae, from 72 to 88 days for seven-instar larvae and from 80 to 111 days for larvae having more than seven instars.

A Comparison of Insectary Records with Field Records: Larvae were collected from the field at weekly intervals and their stage of development recorded as a check against the data secured from individuals reared under insectary conditions. Table X is presented to show the close correlation that exists between the two sets of data. It will be noted that the head capsule measurements and stages of development of the two lots of larva are practically identical.

Preparation for Pupation: When a larva becomes full grown it usually deserts the plant and its old retreat burrow and forms a rather small oval pupal cell just below the surface of the soil. In slough grass sod this cell is often so close to the surface that only a thin layer of leaf mulch is left to cover it. When the cell is completed the larva passes into the prepupal stage (fig. 13),

TABLE X. DEVELOPMENT OF FIELD COLLECTED AND INSECTARY REARED LARVAE COMPARED. 1928.

Date	Ave. width of head capsule (mm.)		Percent of individuals in each instar.												
			Field collected larvae						Insectary reared larvae						
	F.C.	I.R.	I	II	III	IV	V	VI	I	II	III	IV	V	VI	VII
Apr. 30	.315	.313	100						100						
May 7	.474	.491	12	88					4	92	4				
May 14	.738	.750		13	87					2	96	2			
May 21	.995	1.01			11	89					4	96			
May 28	1.61	1.65				9	91						100		
June 4	1.65	1.73					85	15					83	*17	
June 11	1.79	1.86					44	56					46	*54	
June 18	2.34	2.50						†100						°46	54
June 25	2.49	2.50						†100						°46	54
July 2	2.44	2.50						†100						°46	54
July 9	2.45	2.58						†100						°46	54

F.C.: Field collected.
I.R.: Insectary reared.
†VI and VII instar larvae can not be separated accurately.
*Not last instar.
°Last instar.

in which the body contracts longitudinally, the thorax becomes curved whereby the head is thrown forward almost to the legs which are stiff and functionless. After spending from one to five days in this condition the insect sheds its last larval skin and the pupa is revealed.

PUPA

Pupation occurs over a period of about a month, beginning usually the last week of June and continuing well toward the end of July. The earliest date of pupation, June 26, and the latest, July 29, both occurred during the 1929 season (table XI). Immediately after transformation the pupa is white in color but within a few hours the wing pads and ventral portion of the body become yellow and dorsal portion reddish brown. In the next few days the color gradually changes to amber. About the fourteenth day four characteristic dark lines (part of the adult color pattern) appear in the wing pads, and within the next three or four days the color changes to dark brown or black in conformity with the color pattern of the adult, which emerges in one or two days.

The duration of the pupal stage is quite variable and is influenced greatly by prevailing temperatures and to some extent by a number of other factors. The mean daily temperature during the pupal period in 1928 was two degrees lower and in 1929 three degrees lower than in 1927, and as a result the pupal period

TABLE XI. DATE OF PUPATION. SUMMARY.

Year	First	Last	Modal average
1927	June 28	July 16	July 6
1928	June 30	July 23	July 7
1929	June 26	July 29	July 5

TABLE XII. PUPAL PERIOD

Number of days	1927		1928		1929	
	Male	Female	Male	Female	Male	Female
12		1				
13		1				
14		1				
15	1	1				
16	2	3				
17	1	5		5		
18	2	1	11	8		
19	2	1	20	12	1	1
20	1		17	12	4	7
21	1		16	19	7	13
22			12	7	17	10
23			1	2	10	6
24					2	3
Total	10	14	77	65	41	40
Average duration	17.90	16.00	20.01	19.94	21.90	21.55

was prolonged. This is shown in table XII. An analysis of pupal records showed that in many instances individuals which had pupated on the same day and which had been kept under the same conditions (sometimes in the same container) showed variations of from one to five days in the duration of their pupal stages. These variations are not due to sex differences, for very often the first and last individuals to emerge were of the same sex. The records indicate that the length of the larval stage, especially the last instar, may have a slight influence on the length of pupal stage, but this factor alone does not explain differences as large as four and five days.

ADULT

Emergence: At the end of the transformation period the pupa by a series of violent contortions makes an opening thru the top of its chamber. Then the anterior end of the pupal case is slit across the vertex and along the margins of the wing sheaths so as to permit the adult to make its exit. The wings, which at first appear very small and distorted, gradually expand. First they become somewhat convex, then more or less balloon-like and finally straighten out into their normal shape. During the next 30 or 40 minutes the fully expanded wings are held vertically over the back to dry, after which time they are dropped into their normal position over the back and the moth is ready for its initial flight. As is indicated in table XIII the time required for the whole operation of emergence varies from 44 to 57 minutes.

Most of the moths emerge at night, but a few have been observed to come out during the late afternoon. It seems probable that falling temperatures such as occur during the late afternoon and evening stimulate emergence, and that temperatures between 70° and 75°F. are optimum. On July 24, 25 and 26, 1928, ob-

TABLE XIII. RECORDS ON THE TIME OF EMERGENCE OF ADULTS. (1928)

Date	Number of specimens	Splitting of pupal case	Free from pupal case	Wings expanded	Ready for flight	Total time
7–25	1	10:15 p.m.	10:17 p.m.	10:45 p.m.	11:03 p.m.	48 min.
7–26	1	9:40 p.m.	9:45 p.m.	10:00 p.m.	10:37 p.m.	57 min.
7–26	1	10:43 p.m.	10:50 p.m.	11:13 p.m.	11:27 p.m.	44 min.
7–26	1	11:01 p.m.	11:05 p.m.	11:27 p.m.	11:50 p.m.	49 min.
7–26	1	11:09 p.m.	11:15 p.m.	11:41 p.m.	12:01 a.m.	52 min.

servations were made to determine the hour at which the peak of emergence occurred. The results of these observations (table XIV) indicate that the hours of emergence are variable but that the peak will usually occur soon after the temperature drops below 75°. In this connection it is interesting to note that on three different nights when the temperature failed to drop below 75°, the number of moths which emerged was low, while in each case the number which emerged the following night was abnormally high. Emergence during the cooler portions of the night seems to favor self-preservation, because moths attempting to emerge at high temperatures and low humidities are frequently badly deformed.

The dates of adult emergence are shown in table XV. The earliest emergence recorded was July 16; the latest Aug. 17, and the peak or point of maximum emergence occurred during the last week of July.

There is very little difference in the time of appearance of the two sexes, altho as a rule the male sex predominates for the first few days after which the females outnumber the males (table XV).

Sex Proportions and Mating: Of the 290 individuals tabulated in table XV, 158 or approximately 54 percent were males and 132 or approximately 46 percent were females. This indicates that the two sexes occur in about equal numbers.

Mating usually takes place the first night after emergence. Before copulating the female usually comes to rest on the side of

TABLE XIV. SHOWING THE EFFECT OF TEMPERATURE ON THE TIME OF ADULT EMERGENCE. (July 1928)

Hour	Date					
	24		25		26	
	No. emerged	Temp.	No. emerged	Temp.	No. emerged	Temp.
4 p.m.		88		90	1	78
6 p.m.		88		87	2	72
8 p.m.		86	1	82	6	72
10 p.m.		80	4	75	4	72
12 m.	1	74	8	73	3	70
2 a.m.	6	70		70		68
4 a.m.	4	68		68		66
6 a.m.	2	68		70		67
8 a.m.		76		82		70

TABLE XV. DATES OF ADULT EMERGENCE.

Date	1927		1928		1929	
	Male	Female	Male	Female	Male	Female
July 16	1		1			
17						
18			1			
19	1	1			1	
20			5	4	1	
21			4	1	3	
22		1	12	4	3	2
23		1	10	11		1
24	1		7	5	1	2
25	1	1	7	7	1	1
26	2		11	4	6	5
27	1	2	7	5	5	2
28	1	2			1	2
29	1	2			3	3
30	1	1	2	2	3	2
31				1	4	4
Aug. 1	1	1			1	3
2			1	2		
3			12	4	3	5
4	1		4	4	2	1
5	1	1	7	9	1	2
6			4	4		
7			3	2	3	
8				1	2	
9				2		
10						
11						
12				3		2
13					1	3
14						1
15						
16					1	2
17					1	1
Total	13	13	98	75	47	44

the cage or on a stem of grass, slightly raises the tip of her abdomen and passively awaits the arrival of a male. Upon making his appearance the male flutters excitedly about for a time but finally alights near the female and immediately attempts to clasp with her. The pair remain in coition for from 10 to 110 minutes.

Oviposition: Altho the preoviposition period varies from one to six days, the greatest number of females begin laying the second night following emergence. The time of mating greatly influences the length of the preoviposition period. Unfertilized females usually hold their eggs until just before death, when a portion of them may be deposited. The oviposition period varies from three to seventeen days with an average of six and two-tenths days. The moths do not always lay eggs every day during the oviposition period, but as a rule a moth which has once begun to lay will deposit a few eggs each day until all have been deposited.

The postoviposition period ranges from none to nine days with an average of two and three-tenths days. Five out of forty-one females laid eggs during the day on which death occurred.

Oviposition occurs at night. Shortly after sundown the females begin to deposit their eggs. In our cage experiments ovi-

Fig. 13. Larva in pre-pupa stage x 1½.

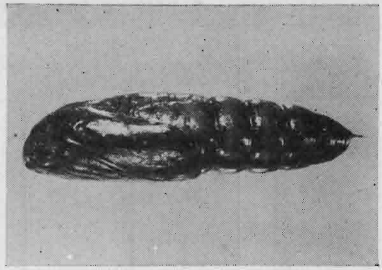

Fig. 14. Pupa of the four-lined borer, twice natural size.

position was at its peak between 9 and 11 o'clock, and only a few stragglers laid after midnight.

The female first flutters about among the plants apparently seeking a suitable place to deposit her eggs. Upon alighting on a plant the tip of the abdomen is immediately turned downward and the ovipositor extended to seek about for a crack or crevice in which to oviposit. When a desirable location is found she deposits a mass of from one to one hundred eggs without changing her position. The number of eggs deposited by individual females on particular days and during their whole lives varies greatly (table XVI). In most cases from 50 to 240 eggs are laid on the first night and successively smaller numbers each day thereafter. In cage experiments, where the eggs were removed daily, the total number of eggs deposited by a female varied from 17 to 812 with an average of 296. In another set of experiments where the moths were caged over both living and dead grasses and left undisturbed, the limits of variation remained about the same, but the average was raised to 519. This would

TABLE XVI. EGG LAYING PERIOD AND LIFE ACTIVITY CHART OF 10 FEMALES. (1928).

Record number	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Total No.
77	E	M	103	146	20	77		D					306
78	E		89	101	32	90	112		47			D	471
81	E	M	215	53	81				D				349
83	E	M	214						D				214
86	E		60	117	166		35	45	D				423
87	E	34	70	65	52	68	62	45	56	D			452
76	E									79	D		79
90	E	65	169	33	D								267
91	E	M	154					D					154
107	E		6	130		D							136
Average of those laying		49.5	120	92.1	70.2	78.3	69.7	45	56	79			
Average of 10		9.9	108	64.5	35.1	23.5	20.9	9.0	5.6	79			284

E emerged. M mated. D dead.

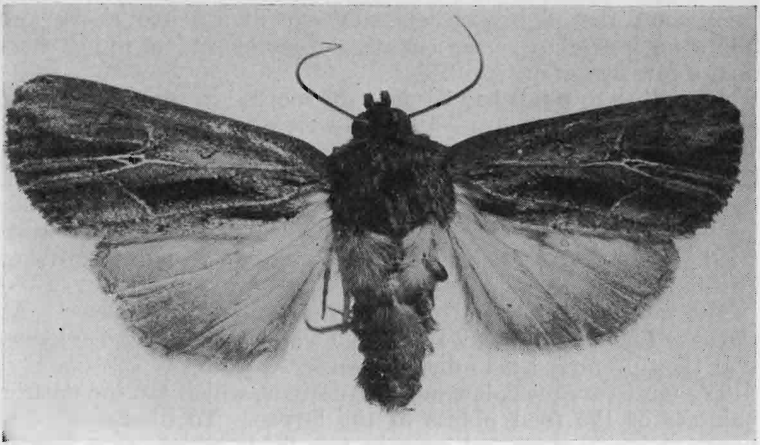

Fig. 15. Adult moth, twice natural size.

indicate that the moths withheld a portion of their eggs when placed under extremely artificial conditions.

The moths oviposit freely on different kinds of grasses, and as a rule the eggs are placed well-down under the leaf sheath or in some rolled or folded leaf (fig. 16).

Longevity: Adult males lived from three to nineteen days, with an average length of life of eight and five-tenths days. Females lived from five to twenty-one days, with an average of eight and six-tenths days. Since most of the moths emerge during the hottest part of the summer their rate of metabolism is high and their length of life is comparatively short. Moths placed in a cool cellar lived from seven to twenty-nine days. Availability of water was an important factor in determining their length of life. Moths deprived of water invariably died in less than a week. On the other hand it did not appear that food was very essential. Moths supplied with sweetened water lived no longer than those given only distilled water.

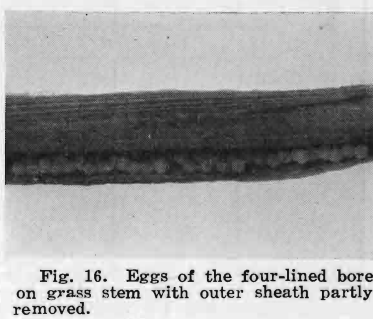

Fig. 16. Eggs of the four-lined borer on grass stem with outer sheath partly removed.

General habits: The adult moths are seldom seen in the field even in localities where they are known to be abundant. During the day they remain hidden under leaves and in dense grass where they are not readily observed nor easily disturbed. Shortly after sundown they become somewhat active and begin to flutter among the plants. Their sluggish flights are short and follow an irregular, zigzag course, the moths seldom flying more than a few feet at a time.

According to published records the moths are sometimes taken at lights, but in the opinion of the writer this is an unusual occurrence. Repeated efforts were made to attract the moths to lights, and in practically all cases the results were negative. The lights used varied from a kerosene lantern to a 100 watt Mazda lamp. Both bright and dim automobile head lights also were tried. Only four moths, three males and one female were taken at lights.

The moths were not attracted to sweetened substances. Altho caged moths did drink sweetened water there was no evidence that they preferred it to distilled water.

The moths frequent low moist situations, which are the natural habitats of the food plants of the larvae. To illustrate: The borer seriously damaged corn in two fields which were located on very low ground. Because no slough grass or other wild hosts could be found in the immediate vicinity it was difficult at first to account for the presence of the borer. It was later found, in both cases, that a good stand of heavily infested *Spartina* occurred on considerably higher ground not more than half a mile away from the field. Apparently the moths had been attracted from their natural host to the environmental conditions existing in the lowlands.

SEASONAL HISTORY

The eggs of *Luperina stipata* are laid on the stems and leaves of grasses during late July and August but do not hatch until April or May of the following spring. The newly hatched caterpillars make their way into the young grass plants. Several

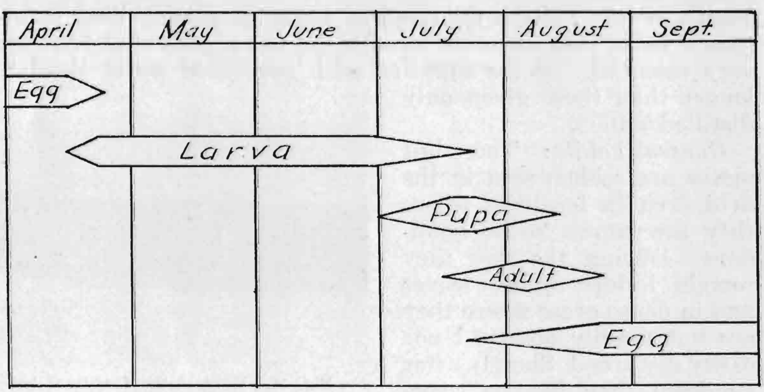

Fig. 17. Seasonal history of the four-lined borer.

plants may be destroyed during the course of the larval feeding period which usually lasts from 70 to 85 days. Transformation to the pupal stage takes place in an especially constructed cell in the soil, beginning about July 1 and continuing up to about July 20. The adult moths emerge during late July and early August and deposit their eggs on the grasses where they remain over the winter. The seasonal history is illustrated graphically in fig. 17.

NATURAL CONTROL

There are several natural enemies of the four-lined borer, two or three of which are of major importance. They are represented by: two Diptera, seven Hymenoptera, four Coleoptera, three Hemiptera, two mammals, one bacterial disease and two fungus diseases. The amount of parasitism in the case of larvae collected from slough grass varied from 8 to 67 percent, but it should be noted that very few parasites were reared from larvae taken from corn. Two hundred and fifty larvae taken from a corn field did not yield a single parasite, while a lot of 201 larvae taken from slough grass in a near by fence row was 37 percent parasitized.

Parasitic Insects: *Masicera senilis* Mg.,[1] the most common dipterous parasite, is very active and in many cases it is responsible for over half of the total parasitism. In field collections from 12 to 34 percent of the caterpillars were parasitized by this fly. As a rule only one maggot emerges from a single host, but the emergence of two is fairly common, and in one case a single host larva produced three maggots. Larvae pupated from July 1 to 22 and the flies emerged from July 12 to Aug. 6. This species has been reared from a number of other stalk borers including *Macronoctua onusta* Grote, *Papaipema nebris* Gn., *P. cataphracta* Grote and two other undetermined species of *Papaipema*.

Three specimens of *Winthemia quadripustulata* (Fab.)[2] were reared. In two cases the parasite maggots emerged from last instar larvae and pupated in the soil, while in the third case the fly emerged direct from a moth pupa, the maggot having pupated within the host. Emergence dates were July 1, 6 and 19, 1929. Altho not an important parasite of *Luperina stipata* this species is very common in the state and is frequently reared from army-worms and cutworms.

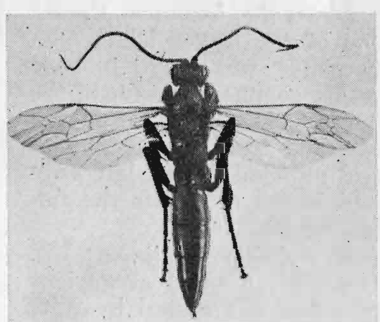

Fig. 18. *Ectopimopha sp.*, an important parasite of the four-lined borer.

Among the important parasitic Hymenoptera attacking

[1]Determined by J. M. Aldrich.
[2]Determined by H. J. Reinhard.

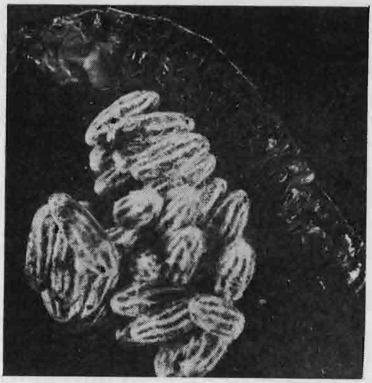

Fig. 19. Parasitized larva and cocoons of *Microphitis gortynae* Riley.

this insect is a large ichneumon fly of the genus *Ectopimorpha* (fig. 18), which is soon to be described by Mr. R. A. Cushman. The stage of development of the host at the time it is attached by the parasite is not known. Pupation takes place within the pupa of the host, and the adults emerge 15 to 20 days after the host has pupated.

Two specimens of a closely related species, *Amblyteles jucundus* Brulle,[3] were also reared from pupae of the borer. This species has also been bred from *Macronoctua onusta* Grote and *Papaipema nebris* Gn. and is reported as a parasite of several cutworms.

Meteorus vulgaris (Cress),[3] a medium small gregarious braconid, parasitizes as high as 12 percent of the larvae collected in the field. Adults emerged from July 2 to 21. Adults that emerged July 9 were placed in a vial with three host larvae, on July 11. Oviposition was not observed, but the host larvae were saved and reared. On July 22 and 23 seven, eleven and fourteen larvae of this parasite emerged from the caterpillars and spun their cocoons. Five days later the adults emerged.

Apanteles laeviceps Ashm.[3] and *A. militaris* Walsh., two common parasites of cutworms, were reared in small numbers.

Lissonota brunnea Cress.[3] one of the larger ichneumon parasites, was found to be a rather common parasite of the borer. The mature larvae emerged from the caterpillar and pupated during late July and issued as adults the following May.

Microplitis gortynae Ril. (fig. 19), a small gregarious parasite, was reared in quite large numbers. It sometimes parasitized as high as 30 per-

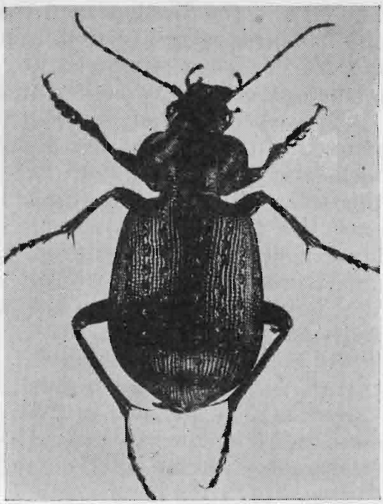

Fig. 20. The fiery Hunter, *Calosoma calidum*, an enemy of the four-lined borer

[3]Determined by R. A. Cushman.

cent of the larvae. From six to twenty-two larvae emerged from a single caterpillar and immediately spun up in reddish brown, ribbed cocoons. The larvae spun their cocoons during the first two weeks of July, and altho the time of pupation was not determined the adults did not emerge until the following May.

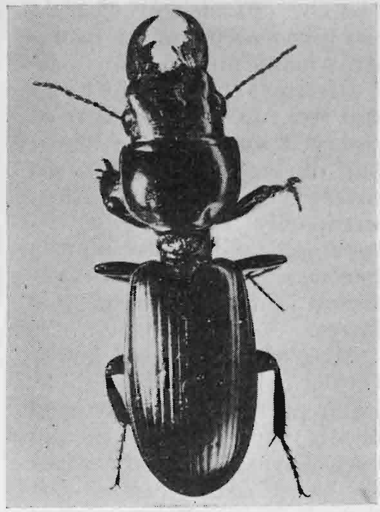

Fig. 21. *Scarates subterranean*, an important predator on the borer.

Predatory Insects: Among the predacious insects the ground beetles are of greatest importance. The "fiery hunter" (*Calosoma calidum* Fab.) (fig. 20) is very active in destroying the caterpillars, and a single beetle may destroy from 50 to 100 or more caterpillars during its life. In cage experiments it was found that nearly full-grown *Calosoma* larvae and adult beetles are both capable of devouring a full-grown caterpillar every day, and adults have been observed to kill as many as three, eating only a part of each one.

Scarates subterranean var. *substratus* Hald. (fig. 21), a large black beetle, was observed to be very common and was one of the most voracious feeders. Like the *Calosoma* beetles they were able to eat one or more larva each day.

Three species of carabids, *Evarthrus colossus* Lec., *E. sodalis* Lec. and *Galerita janus* Fab., have been observed to be quite consistent feeders upon the borers and other noctuid larvae.

Several other species, including *Harpalus caliginosus* Fab., *H. pleuriticus* Kirby, *H. pennsylvanicus* Dej., *Pterostichus permundus* Say, and *P. lucublandus* Say, were found to be commonly associated with the borer in *Spartina* sod, but the extent of their predatory habits was not determined.

Three species of insects belonging to the order Hemiptera were observed to attack young larvae while they were working above ground. Two adults and one nymph of *Podisus maculiventris* (Say), two adults of *Nabis ferus* L. and one undetermined reduviid nymph constitute the total number of observations on hemipterous predators.

Mammals: Moles, which occasionally have runways along fence rows and in infested sod, destroy the pupae and probably some larvae. It is difficult to find undestroyed pupae in the vicinity of a mole burrow. In the same way the short-tailed shrew (*Blarina brevicauda* Say) has been known to destroy many pupae.

Diseases: One bacterial and two fungus diseases were observed to attack the borer, but during the three years covered by this study they were only occasionally encountered and do not appear to constitute a very important factor in the control of this insect.

Most of the diseased larvae turned quite reddish in color. Later part of them developed a soft white fungus growth over the entire body while the others soon became a soft watery mass. Larvae killed by the third type of disease *Cordyceps* sp.[4] develop prominent white fruiting bodies.

Fig. 22. A heavy stand of slough grass, *Spartina michauxiana* Hitchs., the natural host plant of the borer.

CONTROL

The four-lined borer is primarily a weed and wild grass insect. It breeds extensively in common slough grass (fig. 22), and it is more or less accidentally that corn or other crops are attacked. Apparently the eggs are laid at random upon the lowland grasses, and it is only a matter of chance that the young larva finds a suitable host. If the slough grass and other large stemmed grasses which grow in the fence rows and in low poorly drained fields are destroyed, most of the larvae will perish, and the borer population will be so reduced that an outbreak will be practically impossible.

Burning fence rows and grasslands between Nov. 1 and April 1 destroys the eggs, but since most of the parasites spend the winter beneath the surface of the soil they would be uninjured by the fire.

[4]Determination by Dr. J. C. Gilman.

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